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PTO/SB/05 (08-00)
Approved for use through 10/31/2002. OMB 0651-0032
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	07136.00002(UBE2)
First Inventor	MASAHIKO KITAJIMA
Title	NEW IMPROVED EQUIVALENT CIRCUIT...
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [X] Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [ ] Applicant claims small entity status. See 37 CFR 1.27.
3. [X] Specification [Total Pages 14] (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [X] Drawing(s) (35 U.S.C. 113) [Total Sheets 12]
5. Oath or Declaration [Total Pages]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) (for continuation/divisional with Box 17 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1 63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. [X] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [X] Power of Attorney
11. [ ] English Translation Document (if applicable)
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [ ] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. [ ] Other: ....

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:
[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No ________/________
Prior application information Examiner ____________ Group / Art Unit ____________

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

18. CORRESPONDENCE ADDRESS

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Signature		Date	Oct 3, 2000

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FEE TRANSMITTAL for FY 2000

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT ($)

Complete if Known	
Application Number	To Be ASSIGNED
Filing Date	HEREWITH
First Named Inventor	MASAHIKO KITAJIMA
Examiner Name	To Be Assigned
Group Art Unit	To Be Assigned
Attorney Docket No.	UBE2

METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number

Deposit Account Name

☐ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

☐ Applicant claims small entity status. See 37 CFR 1 27

2. ☒ **Payment Enclosed:**

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	690
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 690

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	16	-20** =	0	X	0	=	0
Independent Claims		- 3** =	0	X	0	=	0
Multiple Dependent					0	=	0

***or number previously paid, if greater, For Reissues, see below*

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 690

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	605	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	40
146	690	246	345	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	690	249	345	For each additional invention to be examined (37 CFR § 1 129(b))	
179	690	279	345	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) ____________________

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 730.00

SUBMITTED BY				Complete *(if applicable)*	
Name (Print/Type)	MAXIM H. WALDBAUM	*Registration No. (Attorney/Agent)*	26,244	*Telephone*	(212) 632-8435
Signature	[signature]			*Date*	October 3, 2000

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Application

for

United States Letters Patent

To all whom it may concern:

Be it known that

Masahiko Kitajima, Kosuke Nishimura and Hiroshi Nakamura

have invented certain new and useful improvements in

IMPROVED EQUIVALENT CIRCUIT FOR DIELECTRIC CERAMIC FILTER

of which the following is a full, clear and exact description.

IMPROVED EQUIVALENT CIRCUIT FOR DIELECTRIC CERAMIC FILTER

FIELD OF THE INVENTION

This invention enables development and production of high electrical performance filters in sizes much smaller than what is capable with existing technologies, using an improved equivalent circuit.

BACKGROUND OF THE INVENTION

A ceramic body with a coaxial hole bored through its length forms a resonator that resonates at a specific frequency determined by the length of the hole and the effective dielectric constant of the ceramic material. The holes are typically circular, or elliptical. A dielectric ceramic filter is formed by combining multiple resonators. The holes in a filter must pass through the entire block, from the top surface to the bottom surface. This means that the depth of hole is the exact same length as the axial length of a filter. The axial length of a filter is set based on the desired frequency and available dielectric constant of the ceramic.

The ceramic block functions as a filter because the resonators are coupled inductively and/or capacitively between every two adjacent resonators. These components are formed by the electrode pattern which is designed on the top surface of the ceramic block couplings and plated with a conductive material such as silver or copper.

Ceramic filters are well known in the art and are generally described for example in U.S. Patent Nos. 4,692,726, 4,823,098, 4,879,533, 5,250,916 and 5,488,335, all of which are hereby incorporated by reference as if fully set forth herein.

With respect to its performance, it is known in the art that the band pass characteristics of a dielectric ceramic filter are sharpened as the number of holes bored in the ceramic block are increased. The number of holes required depends on the desirable attenuation properties of the filter. Typically a simplex filter requires at least two holes and a duplexer needs more than three holes. This is illustrated in Figure 9 where graph 10 represents the filter response with fewer holes than graphs 12 and 14. It is apparent that graph 14 which is the response of the filter with the most holes, is the sharpest of the three responses shown. Referring to Figure 10, it can be seen that the band pass characteristic of a particular dielectric ceramic filter is also sharpened with the use of trap holes bored into the ceramic block. Solid line graph 21 represents the response of a filter without a high end trap. Dashed line graph 23 represents the response of the same filter with a high end trap.

Trap holes, or traps as they are commonly referred to, are resonators which resonate at a frequency different from the primary filter holes, commonly referred to simply as holes. They are designed to resonate at undesirable frequencies. Thus, the holes transmit signals at desirable frequencies while the traps remove signals at the undesirable frequencies, whether low end or high end. In this manner the characteristic of the filter is defined, i.e. high pass, low pass, or band pass. The traps are spaced from holes a distance greater than the spacing between holes so as to avoid mutual interference between the holes and traps. As shown in Figure 11, whereas holes 31 are separated from each other a distance equal to D, a distance of 2D is placed between trap 33 and the transmission hole nearest to trap 33. The precise distance between trap and transmission pole is one of design choice for achieving a specified performance, but it is preferably 1 to 10 mm. Traditionally, the traps will be spaced from 1.5D to 2D from the holes.

Conventionally the holes 41 and traps 43 in a ceramic filter are positioned along a straight line. This design together with the spacing requirements addressed above limits the extent to which a filter may be reduced in size. Specifically, the performance characteristics of a given filter are a function of its width, length, number of holes and diameter of holes. The usual axial length L is 2 to 20 mm. The width w is determined by the number of holes. The usual width of the block filter is 2 to 70 mm. Reducing the number of holes, the diameter of the holes, or the spacing between holes, will effect the performance. Accordingly, it is desirable to have a design for a dielectric ceramic filter which can effectively reduce the size of a given filter while maintaining its given performance characteristics.

Equivalent circuits are generally those circuits with the same overall current, impedance, phase, and voltage relationships as a more-complicated counter part that it usually replaces.

There is a need for dielectric ceramic filters used in advanced communication applications such as CDMA and TDMA cellular phones with higher electrical performances and a smaller physical size. However the existing methods to develop a filter with higher electrical performance is to add additional transmission poles and/or trap resonators in a filter, which causes an increase in the size of the new filter.

SUMMARY OF THE INVENTION

This invention describes a new design for increasing the electrical performance without increasing the size of a high performance ceramic filter. To achieve this purpose, this invention describes a new equivalent circuit of dielectric ceramic filter with a new printed pattern on the filter to realize the new equivalent circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts a typical equivalent circuit of a prior art filter.

Figure 2 illustrates the typical printed pattern of a prior art filter designed in accordance with the equivalent circuit of Figure 1.

Figure 3 illustrates the equivalent circuit for a filter designed in accordance with the present invention. This new equivalent circuit design has a similar electronic performance as the prior art filter of Figure 1, but is physically smaller.

Figures 4A-B illustrate one preferred embodiment of a printed pattern for a filter designed to perform as the equivalent circuit of Figure 3. C1 is the capacitance of coupling between input/output electrode and resonator θ1; C2 is the capacitance of coupling between θ1 and θ2; and C3 is the capacitance of coupling between input/output electrode and resonator θ2. Z is the inductance of coupling between θ1 and θ2. The shaded portion of the electric pattern, weakens C2. As a result of the weakened C2, Z is relatively strengthened.

Figure 5 compares the similarity in electrical performance between the filter designed in accordance with the present invention shown in Figure 3 and a prior art filter, such as shown in Figure 1. The rigid line is the electrical performance of the present invention shown in Figure 3 and the broken line is that of prior art filter shown in Figure 1.

Figure 6 illustrates the equivalent circuit for a duplexer designed in accordance with another embodiment of the present invention.

Figure 7A-B illustrates one preferred embodiment of a printed pattern for a duplexer designed to perform as the equivalent circuit of Figure 6. Figures 7C-D, 7E-G, 7G-H and Figures

7J-K and additional preferred embodiments and their equivalent circuits.

Figure 8 illustrates another preferred embodiment of a printed pattern for a filter designed to perform as the equivalent circuit of Figure 3. This filter has two (2) transmission poles and one (1) trap resonator, but it can work as a filter with three (3) transmission poles and one (1) trap resonator.

Figure 9 illustrates the increased sharpness of the band pass response of a dielectric ceramic filter as the number of holes in the filter increase.

Figure 10 illustrates the effectiveness of traps in removing high end frequencies.

Figure 11 is representative of the spacing between holes and hole and trap on a conventional ceramic block filter.

DETAILED DESCRIPTION OF THE INVENTION

One embodiment of this invention is a filter with 4 transmission poles and 2 trap resonators (total 6 holes), shown in Figures 4A-B. Capacitances C1, C2 and C3 are as shown in Figure 4B.

Resonator $\theta 1$ functions as a transmission pole by the coupling of Z1 and C2, so that $\theta 1$ can compose 5 transmission poles by cooperation with the other 4 transmission poles of $\theta 2$, $\theta 3$, $\theta 4$ and $\theta 5$. (See Figure 3)

Furthermore, $\theta 1$ also functions as a trap resonator by adjusting the coupling of C1, C2 and C3 as to be $C1>C3>C2$. Thus, $\theta 1$ can work as both a transmission pole and a trap resonator. Due to the unique pattern of the filter, $\theta 1$ can act as both a trap resonator and transmission pole, thus reducing filter size by eliminating one transmission pole. (See Figures 3 and 4A-B)

This means higher electrical performance can be achieved while having a smaller filter size by using this new design of equivalent circuit.

A new electrode pattern of conductive material was developed, as shown in Figs. 4A and 4B to realize the effect of the new equivalent circuit. Each value of W, L, X1 and Y1 in Fig.4A are the following ranges.

W: $0.5\text{ mm} \geq W \geq 0.1\text{ mm}$

L: $3.0\text{ mm} \geq L \geq 0.5\text{ mm}$

X1: $4.0\text{ mm} \geq X1 \geq 1.0\text{ mm}$

Y1: $2.0\text{ mm} \geq Y1 \geq 0\text{ mm}$

Fig. 4B shows parameters C1, C2 and C3. C1 is controlled by the distance between pattern 1 of conductive material for input/output electrode and pattern 3 of conductive electrode connected to conductive material on the inner surface of hole of $\theta 1$ resonator, and C3 is controlled by the distance between pattern 1 and pattern 4 of conductive material connected to conductive material on the inner surface of hole of $\theta 2$ resonator. C1, C2 and C3 are capacitances of coupling as described above in Figure 4B. Z is an inductive coupling and is controlled by the pattern 2 of conductive material that is opposed to the pattern 1 and is connected to the conductive material on the side wall. The relationship of C1, C2 and C3, to each other is as follows, C1>C3>C2.

Fig. 5 shows the electrical data of the filters developed by the existing technology and by our new technology along with the requested specification. Although the present invention's filter is smaller, due to the less amount of holes, than currently available filters, its performance matches the electrical performance of larger filters using presently available technology. The electrical

performance of the present invention (the filter of Figure 3) is represented by the rigid line as the shown in Figure 5. The electrical performance of a prior art filter (the filter of Figure 1) is represented by the broken line as shown in Figure 5.

We can also apply the concepts of this new filter technology to a duplexer. Figure 7 is a embodiment of a duplexer pattern of the present invention. Figure 6 is its equivalent circuit. Fig. 6 and Fig. 7A-K show examples of new equivalent circuits and printed patterns, as applied to a duplexer. The duplexer of Fig. 6 and 7A-B has eight (8) transmission poles and three (3) trap resonators, but it can work as a filter with nine (9) transmission poles and three (3) trap resonators. In most cases, the higher brand is the receiver band and the lower band is the transmitter band at the mobile phone terminal sides. These designations become reversed at the base station side. However, it is noted that the relationship of the receiver band and the transmitter band, on the one hand, and the higher/lower bands on the other hand are not always consistent.

The frequency of the off line hole at the center of the duplexer is nearly equal to that of higher band. In this case, higher band side is the right side of duplexer in Figure7. One embodiment of the duplexer filter has three input/output pads and three patterns of conductive material connected to those pads. The duplexer filter may or may not have trap holes at both sides of the filter.

Each value of W, L, X1 and Y1 for the duplexer filter are the following ranges.

W: $0.5\text{ mm} \geq W \geq 0.1\text{ mm}$

L: $3.0\text{ mm} \geq L \geq 0.5\text{ mm}$

X1: $4.0\text{ mm} \geq X1 \geq 1.0\text{ mm}$

$Y1$: $2.0 \text{ mm} \geq Y1 \geq 0 \text{ mm}$

The relationship of C1, C2 and C3, to each other is as follows, C1>C3>C2. C1, C2 and C3 are shown on Figure 7B.

According to the above results, this new filter technology can be applied to many filters and duplexers which are of a smaller size with higher electrical performance than currently available filters. The foregoing merely illustrates the principles of the present invention. Those skilled in the art will be able to devise various modifications, which although not explicitly described or shown herein, embody the principles of the invention and are thus within its spirit and scope.

WHAT IS CLAIMED IS:

1. A filter comprising:

a block of dielectric material having a top surface, a bottom surface, two opposing first side-walls connecting said top surface to said bottom surface along the width of said block and two opposing second side-walls connecting said top surface to said bottom surface along the height of said block;

two input/output pads on one of said first side walls;

at least three holes spaced along the width of said block and extending through said block from said top surface to said bottom surface, wherein at least one of said at least three holes which is located on the end of the three holes, and where said at least one hole's center is off a line bisecting the remaining two of the at least three holes;

conductive material substantially covering said bottom surface said first and second

side-wall surfaces and said inner surfaces of said at least three holes;

said each holes have patterns of conductive material on said top surface, surrounding said holes;

said center of said off line hole is a distance Y1 from a center of an hole adjacent to the off line hole, said distance Y1 being perpendicular to the filter's first side walls;

said center of said off line hole is a distance X1, from the center of said adjacent hole, said distance X1 being parallel to the filter's first side walls;

a first pattern of conductive material between said off line hole and the adjacent hole, where said first pattern comprises a first arm of conductive material parallel to the edge of the conductive material of the off line hole and parallel to the filter's first side walls, a second arm of conductive material perpendicular to said first arm of conductive material, and a third arm of conductive material parallel to the first arm of conductive material and perpendicular to the second arm of conductive material said first pattern of conductive material is connected to the first of said input/output pads on one of said first side walls;

said off line hole has a pattern of conductive material surrounding said hole, said edge of said off line hole's pattern of conductive material has a capacitance C2 from the edge of conductive material surrounding the adjacent hole, where C2 is the capacitance between two opposite edges of said offline hole's pattern of conductive material and said adjacent hole's pattern of conductive material;

where said off line hole is next to the first arm of conductive material where capacitance C1 between the conductive material surrounding said off line hole and the first

arm of conductive material, where C1 is the capacitance between the off line hole's pattern of conductive material and said first pattern of conductive material);

a second pattern conductive material opposite the first pattern of material, where said second pattern has a width, W, and a length, L, said second pattern is connected to the conductive material on one of the first side walls; and

a capacitance C3 which is the capacitance between said pattern of hole adjacent to off line hole and said first pattern; and

a third pattern of conductive material between the fifth and sixth holes where said third pattern is connected to said second input/output pad.

2. The filter of claim 1 wherein W: $0.5 \text{ mm} \geq W \geq 0.1 \text{ mm}$, L: $3.0 \text{ mm} \geq L \geq 0.5 \text{ mm}$, X1: $4.0 \text{ mm} \geq X1 \geq 1.0 \text{ mm}$ and Y1: $2.0 \text{ mm} \geq Y1 \geq 0 \text{ mm}$.

3. The filter of claims 1 and 2 wherein **C1>C3>C2.**

4. A duplexer filter comprising:

a block of dielectric material having a top surface, a bottom surface, two opposing side-walls connecting said top surface to said bottom surface along the width of said block and two opposing side-walls connecting said top surface to said bottom surface along the height of said block;

three input/output pads on one of said side-walls;

multiple holes spaced along the width of said block and extending through said block from said top surface to said bottom surface, wherein a first hole is located at a first

location and where said first holes-center is off a line bisecting the remaining holes;

conductive material substantially covering said bottom surface said side-wall surfaces and said inner surfaces of said holes;

said center of said off line hole is a distance Y1 from a center of a hole adjacent to said off line hole, said distance Y1 being perpendicular to the filter's side walls;

said center of said off line hole is a distance X1, from the center of said adjacent hole said distance X1 being parallel to the filter's side walls;

a first pattern of conductive material connected to one of said side walls, where said first pattern is located between said first off line hole and the next adjacent hole to the first off line hole and has a width W and a length L;

a second pattern of conductive material connected to said first input/output pad, where said second pattern is located between a non-off line hole of lower band and the next adjacent non-off line hole of higher band;

where said first off line hole is next to the second pattern of conductive material with a capacitance C1 between the conductive material surrounding said first off line hole and the second pattern of conductive material;

a second capacitance C2 which is the capacitance between the pattern of said next adjacent hole to said first off line hole and said conductive material surrounding said first off line hole; and

a third capacitance C3 which is the capacitance between said second pattern of conductive material and said pattern of said next adjacent hole to said first off line hole.

5. The filter of claim 4 wherein at least two of said holes are transmission poles and

the number of transmission poles is at least two in each of a higher and a lower band of frequencies.

6. The filter of claim 4 wherein the frequency of the off line hole at the center of said duplexer filter is nearly equal to that of a higher band of frequencies.

7. The filter of claim 5 wherein the frequency of the off line hole at the center of said duplexer filter is nearly equal to that of a higher band of frequencies.

8. The filter of claim 4 wherein W: 0.5 mm $\geq$ W $\geq$ 0.1 mm, L: 3.0 mm $\geq$ L $\geq$ 0.5 mm, X1: 4.0 mm $\geq$ X1 $\geq$ 1.0 mm and Y1: 2.0 mm $\geq$ Y1 $\geq$ 0 mm.

9. The filter of claim 5 wherein W: 0.5 mm $\geq$ W $\geq$ 0.1 mm, L: 3.0 mm $\geq$ L $\geq$ 0.5 mm, X1: 4.0 mm $\geq$ X1 $\geq$ 1.0 mm and Y1: 2.0 mm $\geq$ Y1 $\geq$ 0 mm.

10. The filter of claim 6 wherein W: 0.5 mm $\geq$ W $\geq$ 0.1 mm, L: 3.0 mm $\geq$ L $\geq$ 0.5 mm, X1: 4.0 mm $\geq$ X1 $\geq$ 1.0 mm and Y1: 2.0 mm $\geq$ Y1 $\geq$ 0 mm.

11. The filter of claim 7 wherein W: 0.5 mm $\geq$ W $\geq$ 0.1 mm, L: 3.0 mm $\geq$ L $\geq$ 0.5 mm, X1: 4.0 mm $\geq$ X1 $\geq$ 1.0 mm and Y1: 2.0 mm $\geq$ Y1 $\geq$ 0 mm.

12. The filter of claims 4, 5, 6, 7, 8, 9, 10 and 11 wherein C1>C3>C2.

13. The filter of claim 4 where said offline hole is after a line of four holes to the right of said offline hole and four holes to the left said offline hole.

14. The filter of claim 4 where there are two offline holes, the first offline hole having three holes to the left and four non-offline holes to the right of its location, with said second offline hole to the right of the last of said non-offline holes.

15. The filter of claim 4 where there are three offline holes, one on each of the two ends of said filter and the third to the right of two non-offline holes and to the left of three non-offline holes.

16. The filter of claim 4 where there are two offline holes with one offline hole on the left end of said filter and the offline hole having two non-offline holes to the left of said second offline hole and three non-offline holes to the right of said second offline hole.

ABSTRACT

A filter with an equivalent circuit that functions as well as physically larger filters without substantial drop off in performance.

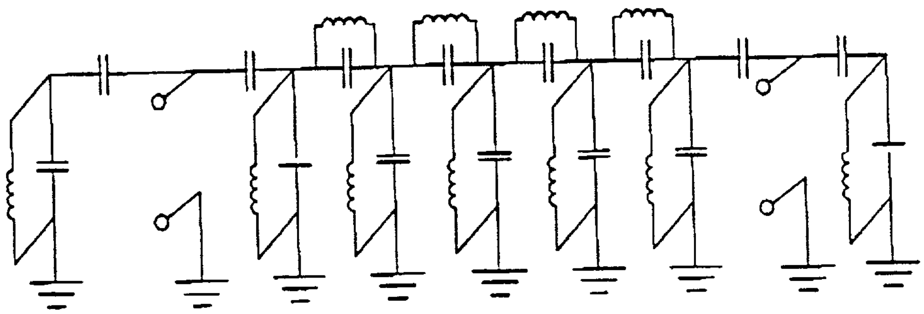

Figure 1

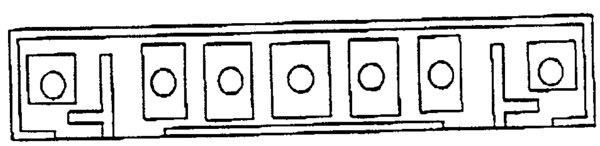

Figure 2

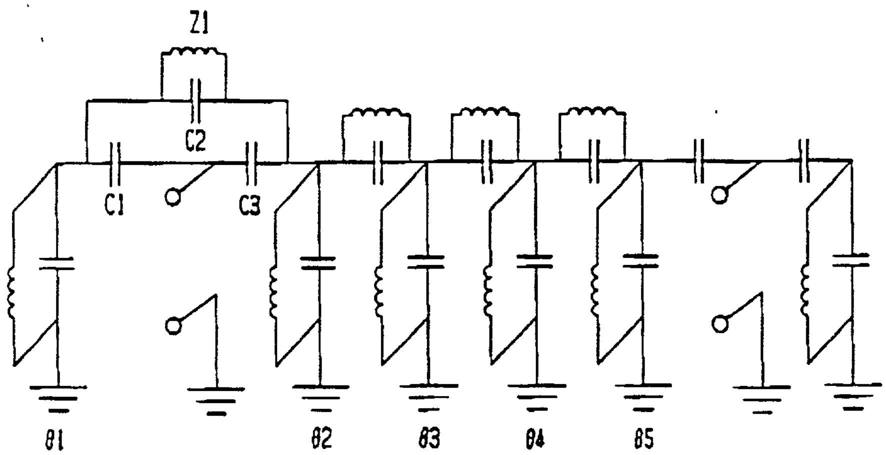

Figure 3

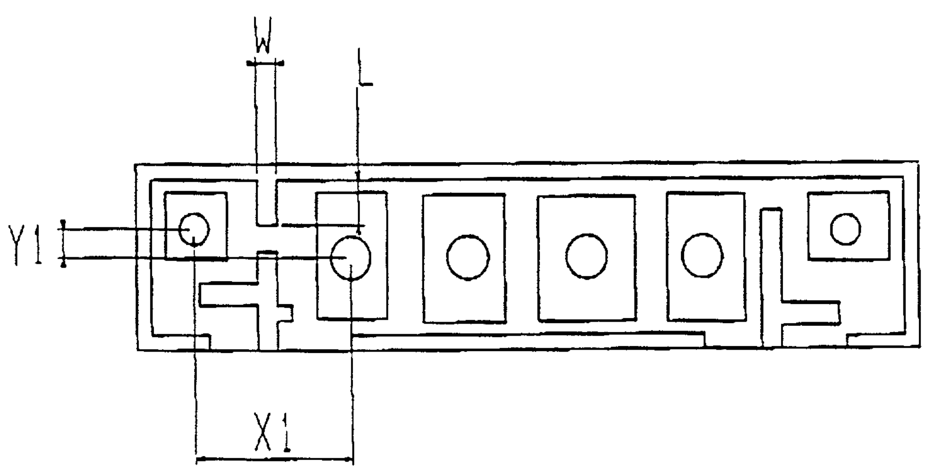

Figure 4A

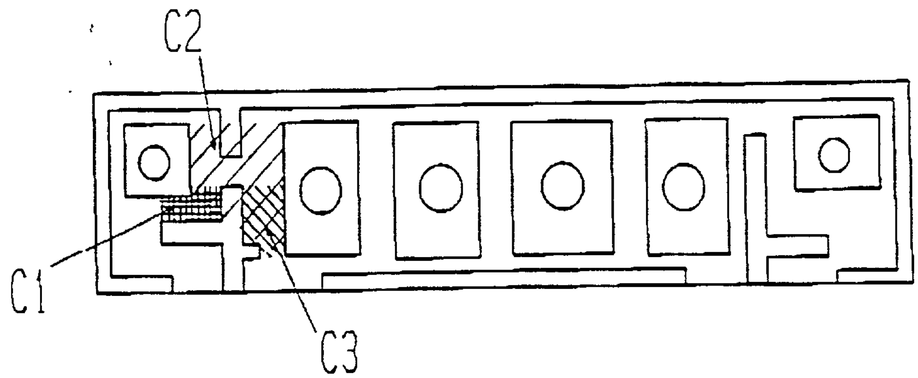

Figure 4B

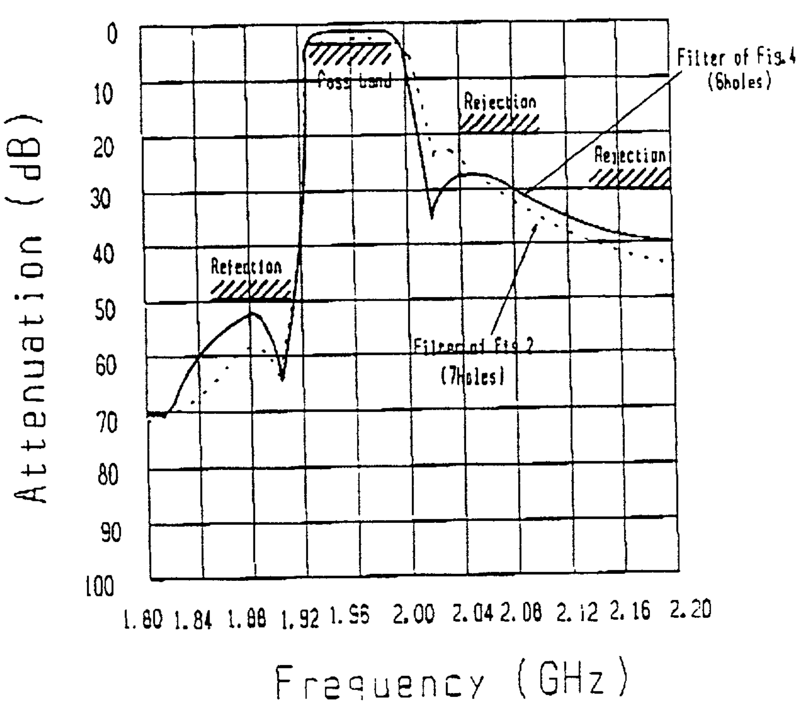

Figure 5

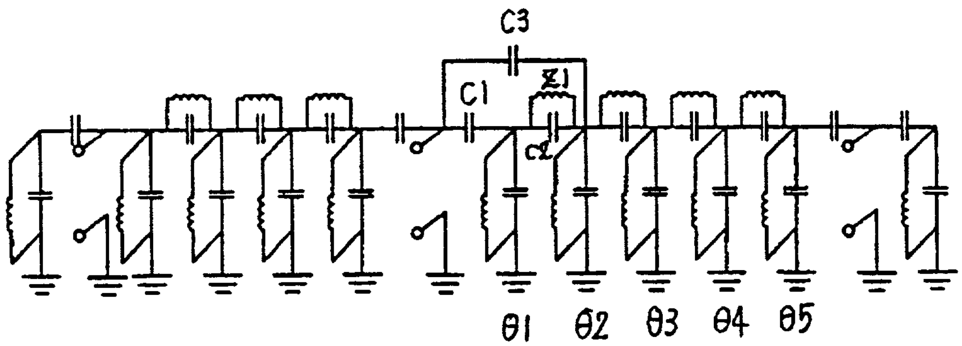

Figure 6

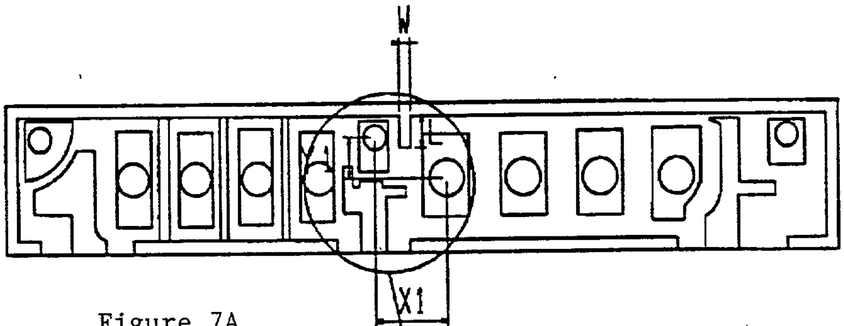

Figure 7A

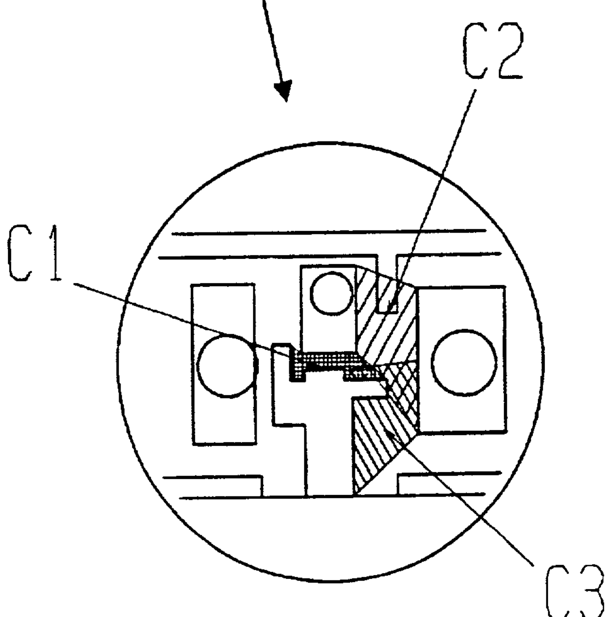

Figure 7B

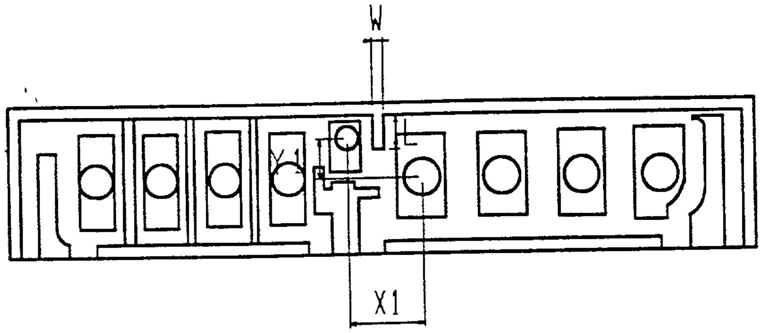

Figure 7C

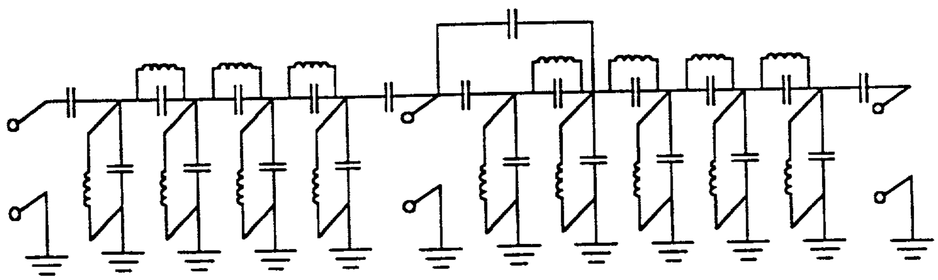

Figure 7D

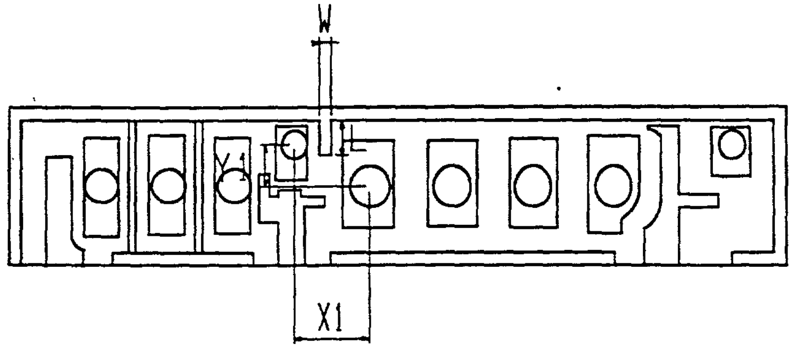

Figure 7E

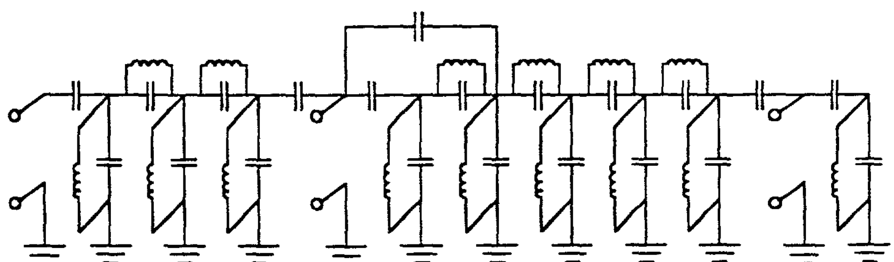

Figure 7F

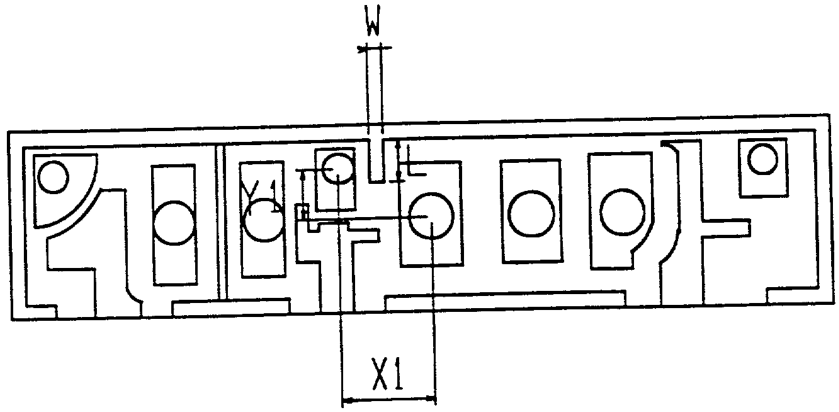

Figure 7G

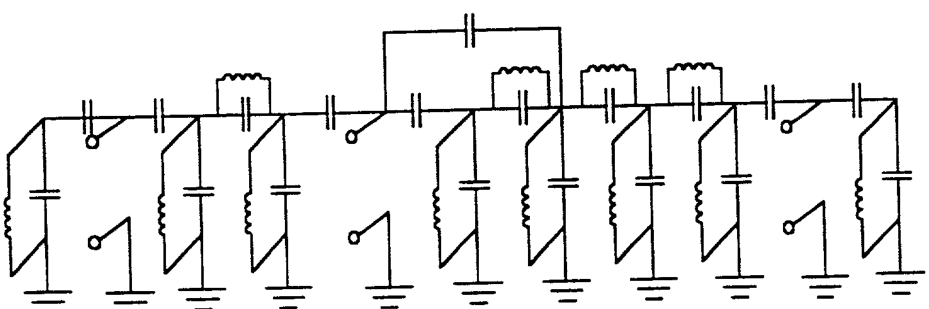

Figure 7H

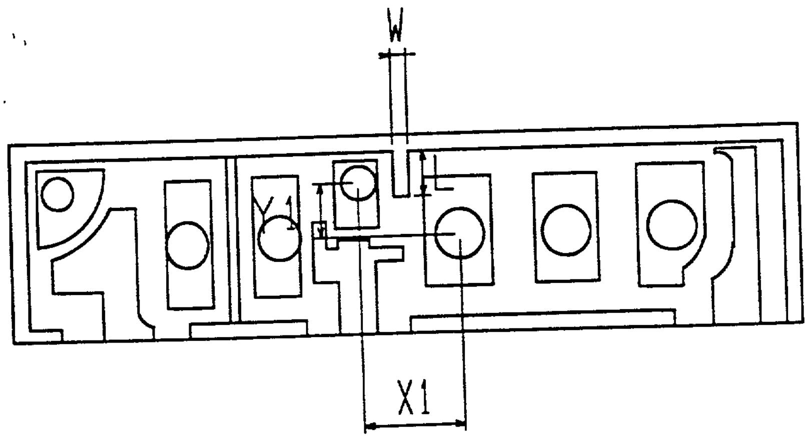

Figure 7J

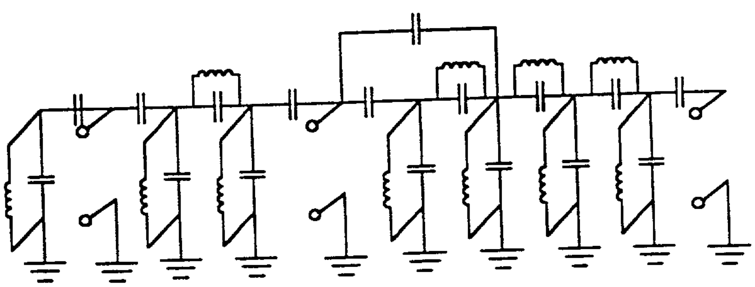

Figure 7K

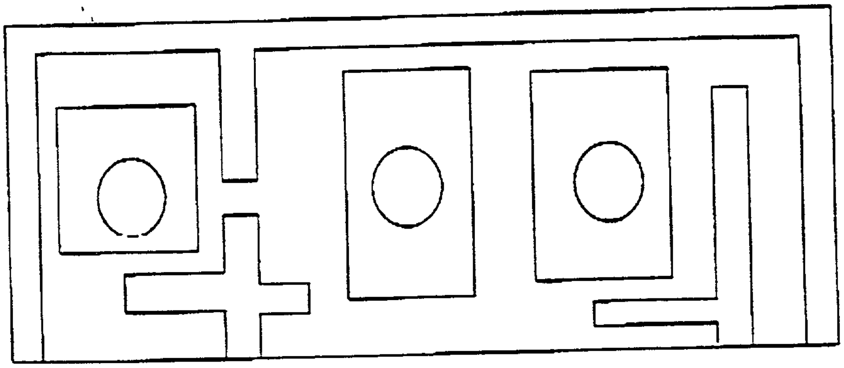

Figure 8B

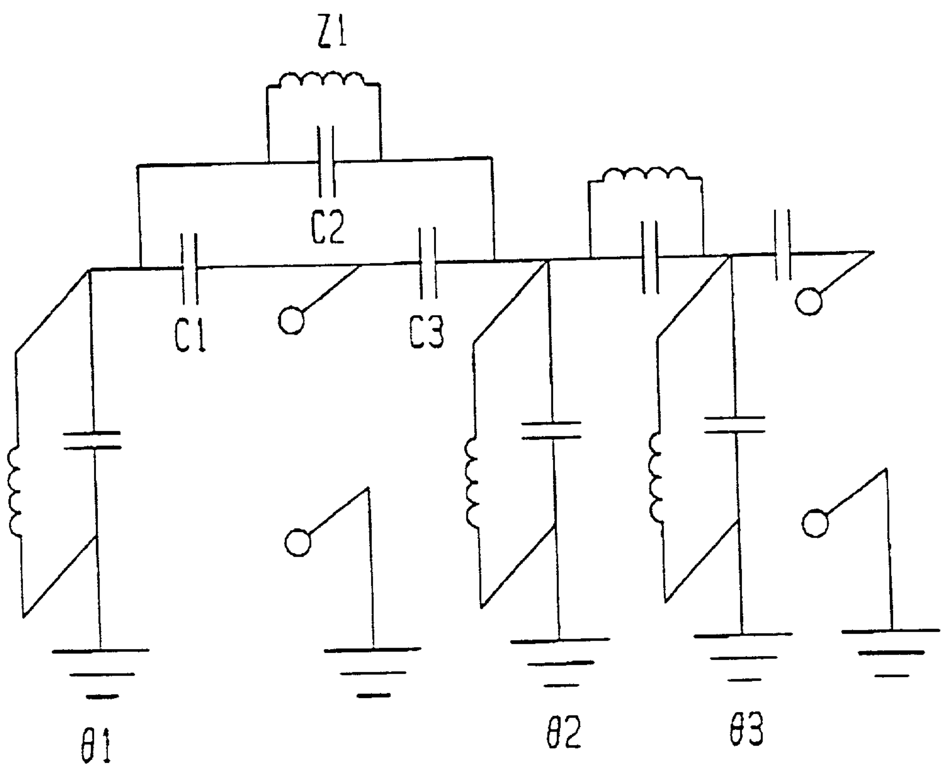

Figure 8A

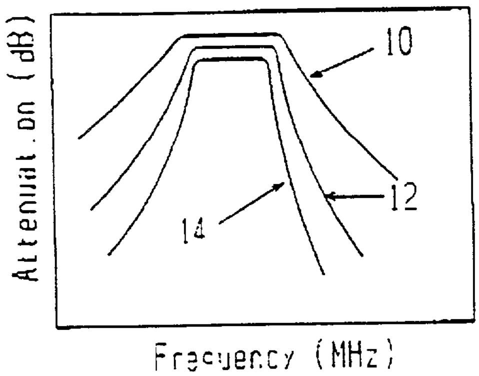

Figure 9

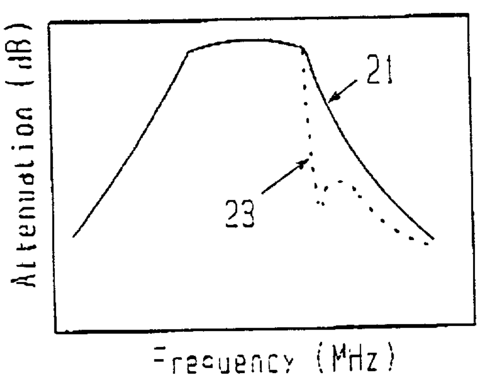

Figure 10

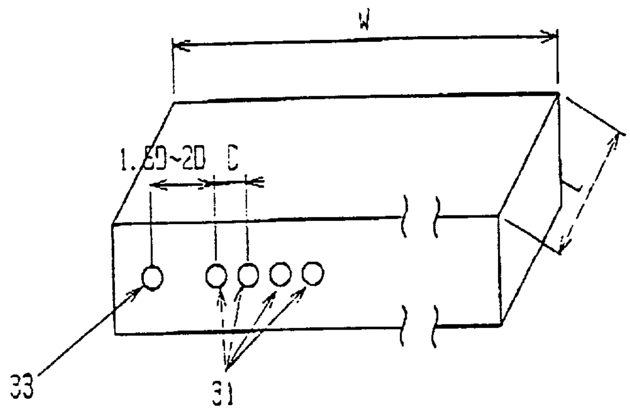

Figure 11

Ube 1-1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: IMPROVED EQUIVALENT CIRCUIT FOR DIELECTRIC CERAMIC FILTER, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim the benefit under Title 35, United States Code, 119(e) of any United States provisional application(s) identified below:

None

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare under penalty of perjury under the laws of the United States of America that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements

and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

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Inventor's signature K. Nishimura Date Sep. 29, 2000

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